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Applying Simulation in a Supply Chain Transformation Case

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APPLYING SIMULATION IN A SUPPLY CHAIN TRANSFORMATION CASE

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ABSTRACT

Supply chain transformation is an emerging service area in the market which aims at helping clients improve their operational efficiency and reduce costs. As a generic technique for the analysis of complex and dynamic systems, simulation could play an important role in this field. This paper presents a case study showing how simulation could be the key enablement for a supply chain transformation project. A methodology and tool developed by IBM China Research Lab has been applied in this joint project with a world-class supplier of home improvement tools. By applying simulation, the client is provided an insightful view about their business processes and inventory allocation strategy, which serves as the basis for the transformation implementation. Financial results show that simulation has addressed the key issues and provided the client accountable evaluation results for decision-making.

Keyword: Supply chain transformation, Simulation, Inventory control

1 INTRODUCTION

Supply chain transformation is an emerging service area in the market, which aims at helping clients transform their supply chain to a more flexible, responsive and resilient supply chain. Clients usually take transformation actions to improve their forecasting accuracy, reduce warehousing costs, improve on-time delivery, etc. Obviously, all transformation initiatives are finally expected to help increase profitability in a short/medium/long term. While in practice, most of supply chain transformation efforts focused on either the implementation of new IT systems or upgrading existing IT systems. These projects generally need considerable investment and take much time to complete. Little attention has been paid in the past to the optimization of existing supply chain operations from managerial point of view. However, such optimization efforts may help firms reduce costs and improve efficiency tremendously with a limited investment. For example, a periodic review and improvement of the inventory control policies for a manufacturing firm may help reduce its inventory carrying cost and improve its customer service level considerably with almost no investment on infrastructure and IT systems.

In the field of supply chain transformation, models and techniques developed by academia, especially by experts from operations research, management science and industrial engineering have a lot to play. As a generic technique, simulation is very suitable for the analysis of complex and dynamic systems [Towill 1991]. Considering this, IBM China Research Lab developed a supply chain transformation methodology and tool to help clients transform their supply chain using simulation and optimization as the core enabling techniques. In this paper, we present a case study to share our experiences from a transformation project with a world-class manufacturer, where simulation was used as the major enabling technique and demonstrated its great value.

This study is conducted by IBM China Research Lab with two partners, respectively Techtronic Industries Co Ltd (TTi) and GS1HK. TTi is a global leader in the design, manufacturing and sales of home improvement and construction products. As one of the leading manufacturers, TTi maintains an expanding stable of well-established and fast growing brands. According to the product features and demand patterns, TTi works on a mixed basis with both original equipment manufacturing (OEM) and original design manufacturing (ODM). In addition to OEM, ODM further provide TTi flexibility in managing its product portfolio and help TTi react responsively to varying customer demands. While how to control inventories along the supply chain and manage the raw material procurement processes at ODMs is still a quite challenging issue.

In such an ODM scenario, the client would like to make a supply chain transformation effort and escalate its supply chain to a more cost-effective, responsive, and resilient one. The objective of the project is to i) identify the best inventory-holding position plus the optimal control policies, and ii) evaluate the impact of central raw material procurement on supply chain performance.

In the remainder part of the paper, Section II gives a brief literature review of inventory control and process simulation. The supply chain transformation project background, simulation model and numerical results are presented in Section III. Some conclusions and perspectives are given in Section IV.

2 LITERATURE REVIEW

2.1 Inventory Control

Inventory management plays a key role in today's business environment, since clients are more and more demanding about service level such as order cycle time, on-time delivery rate, etc. Due to the complexity and stochastic nature of modern supply chains, there are at least two good reasons to set up inventory for raw material/component/final products in a manufacturing scenario.

- Inventory could help reduce the sourcing time of various raw materials and work-in-process components. For unplanned orders with large volume, a buffer stock could mitigate the negative impacts of capacity short on customer service level.
- Holding inventories may help enterprise achieve economies of scale by way of volume discounts and logistics consolidation with full truckloads.

In academia, a variety of inventory control polices have been extensively studied, which are continuous or discrete, deterministic or dynamic. Among those, some of the policies are adopted in industry to support daily business, including base stock, (R, Q), (s, S), etc.

Two approaches are generally employed for inventory analysis, respectively analytical approach and simulation-based approach. Each of the two approaches has its unique features and advantages. Analytical methods are very useful in identifying the best position for inventory holding and the optimal setting of inventory control parameters [Zipkin 2000]. But analytical models are often high abstraction models of business processes for the sake of simplicity and feasibility. While, to obtain detailed and accurate results, one has to include a number of realistic features in the supply chain context.

Comparing to analytical methods, simulation-based approach has its specific advantages in providing an inside view of complex supply chains, especially in the presence of uncertainty and risk. Bhaskaran [Bhaskaran 1998] presented a simulation analysis of supply chain inventory and instability. The impacts of various factors that amplify the dynamics and instability have been studied. In [Petrovic *et al.* 1998], the author proposed several supply chain fuzzy models and a corresponding simulator to assist in decision-making on operational parameters. Two sources of uncertainty, customer demand and external supply of raw material are interpreted and represented by fuzzy sets. But the modeling attention is focused on a supply chain with all facilities in a serial link. The customer demand is confined to a single product. Jansen *et al.* [Jansen *et al.* 2001] designed a simulation model to quantify logistic and financial performances in alternative logistic scenarios for multi-compartment distribution in the catering supply chain.

2.2 Process Modeling and Simulation

Today, business process gained much attention from both academia and industry. A variety of definitions of business process are available in the literature [Hammer and Champy 1993] [Davenport and Short 1990]. The authors [Hammer and Champy 1993] defined a business process as "*a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer.*" A business process is not the same as a business function. It may be contained within a departmental function. But most possibly a business process may cross several different departmental functions and boundaries. For example, "order fulfillment" business process spans usually departments of call center, manufacturing, procurement, distribution and customer service. Business process re-engineering is about "*fundamentally rethinking the radical re-design of business processes to achieve dramatic improvements in critical, contemporary measures of performance such as cost, quality, service and speed.*" [Hammer and Champy 1993]. Business process improvement has a similar definition except that it usually takes a more smooth way rather than a radical approach.

A complete business process model with a necessary level of granularity does give a clear landscape of a supply chain. What's more than that? Given the process model, simulation is a very useful means for its analysis. Process simulation is usually based on token flow semantics, which is described in UML2 superstructure specification with details [UML 2005]. In this paradigm, the simulation model is a sequence of processes, which fall into two categories: control process and executable process. During the simulation, tokens are generated from some beginning processes, and then pass through the succeeding processes. When a token reaches a control process, the token is modified, copied, or directed to some selected processes. When a token reaches an executable process, the process is activated, and an instance of the process is created and executed. Tokens are disposed at the end of flow. Actually, general purpose simulation packages always use similar method. Rockwell's Arena is a typical implementation of token flow semantics [Altiok and Melamed 2001].

A number of commercial-off-the-shell (COTS) tools are available for business process modeling and analysis [Miers and Harmon 2005]. Business process modeling is the mostly supported functionality. However, rare of the tools provide functions beyond that, except some form of simulation capabilities at business process level. Hardly the end user can use these tools directly to analyze supply chain problems such as inventory control. For more details about the evaluation of different COTS tools, readers are directed to [Miers and Harmon 2005] [Hall and Harmon 2005].

3 THE SUPPLY CHAIN TRANSFORMATION CASE

3.1 Project Background

TTi is a leading supplier of home improvement tools in the world. Though, it has encountered some problem when dealing with unforeseen big-volume customer demands. These orders are sometimes not fulfilled on time due to the long order-to-delivery cycle time at the ODM side. This might lead to order cancellation, lost of potential sales or bring additional cost for urgent delivery because of the usage of expensive express transportation. More importantly, it may bring down customer satisfaction level and cause negative influence to the brand image in the long run. According to the investigation, most ODMs do not hold buffer stock for raw materials, which is identified as the major reason for the long order-to-delivery time for ODMs. In this case, keeping some inventory of raw materials is a rather obvious approach to help TTi reduce its response time to customer demands. However, due to the complexity of its operations, it is hard for the management team to locate the most appropriate position for inventory holding and to define the control policy. This is certainly an ideal place where OR/MS techniques could play.

Given this understanding, the objective of this study was set to evaluate and most importantly to quantify how to setup buffer stocks at ODMs. According to the information provided by TTi, we developed a quantitative approach using the simulation capability provided by our tool. The simulation models and corresponding numerical results are presented in the following sections. Note that no real data is provided in this paper due to confidentiality.

Besides the inventory optimization effort, another objective of this study was to evaluate the feasibility and risk of applying central governance model for raw material procurement at ODMs. Currently the raw material procurement process is locally managed at ODMs, out of TTi's management scope. While this sometimes results in product quality failures. TTi would like to first evaluate the possibility to setup a central procurement system and secondly to establish the corresponding business processes. SCOR model [Supply-Chain Council 2006] was used for as-is process modeling and analysis. To-be processes are proposed according to SCOR model, which ensures that the to-be processes would be aligned to best practice and could be easily benchmarked after its implementation. Due to the space limitation, we focus on the presentation of the inventory optimization study in the following sections.

3.2 Modeling

3.2.1 Supply chain structure

The structure of the supply chain under consideration is defined at first (Figure 1). There are three echelons comprising customers, TTi, ODMs and ODMs' 1 tier suppliers. The two most critical customers are selected and modeled, which represents the two largest revenue contributors. Two major ODMs are included as the suppliers of products requested by TTi. Ten 1 tier suppliers of the two ODMs are identified and taken into consideration in this study.

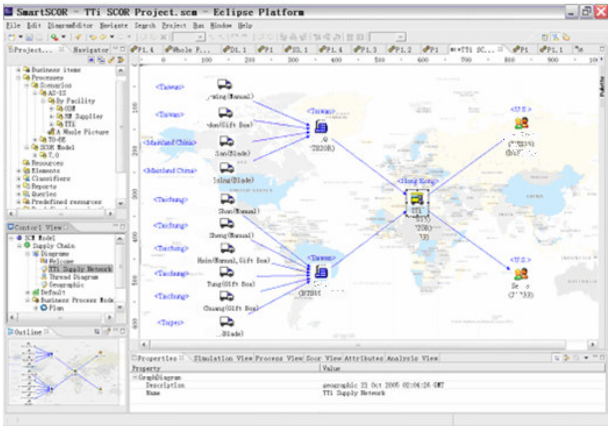

Figure 1: Supply chain network model

Three types of final product are studied in this case. Each has a one-level Bill-of-Material (BOM). Three types of raw materials are included, respectively blade, display box and user manual. Each has a different order-to-delivery lead time, which is defined as the time period elapses between the moment when a procurement order (PO) is issued from ODMs and the moment when corresponding raw materials are received at ODMs. Blade has a much longer order-to-delivery lead time comparing to the other two types, due to the different nature. Accordingly, the inventory control policy for blade represents the major effort of our study.

3.2.2 Business process mapping

Given the supply chain structure, the end-to-end business process is defined as below (Figure 2) comprising four major sub-processes. Each block in the figure represents a sub-process, which consists of a series of activities. Two sub-processes are depicted in Figure 3 and Figure 4.

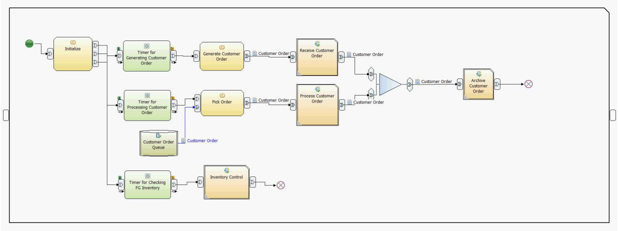

Figure 2: The end-to-end process

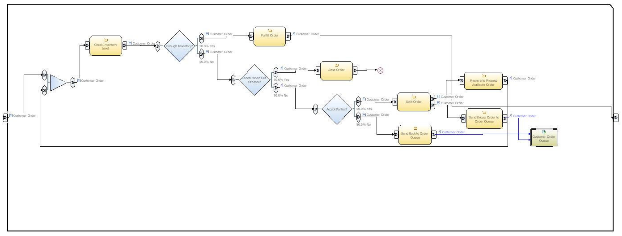

Figure 3: Order fulfillment process

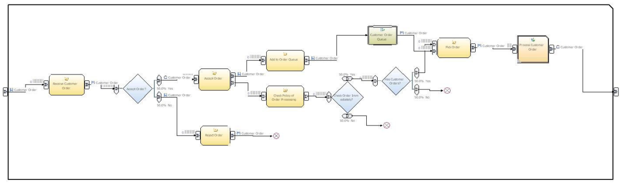

Figure 4: Order receiving process

3.2.3 Operational policy

Considering that TTi outsourced the manufacturing of all of the three products to ODMs, assembly only takes place at ODMs where raw materials from 1 tier suppliers are transformed to final products. Assembly policies are defined as follows. In the as-is scenario, ODMs held no buffers for neither raw materials nor finished products. When TTi send out procurement orders to ODMs, ODMs issue POs to their 1 tier suppliers directly. ODMs start assembly activities only when all BOMs are ready.

Regarding the as-is situation, TTi suggested to introduce some base stock for raw materials at ODMs. Base stock policy with periodical review and replenishment is assumed for inventory control. More specifically, the inventory position of raw materials is reviewed periodically. Whenever the inventory position dropped below the preset base stock level, a replenishment order would be sent out, which bring up the inventory position back to the base stock level.

The limited production capacity of raw material suppliers was identified as one of the major bottlenecks in this supply chain. Accordingly, the production capacity of RM suppliers is taken into consideration in a flexible and complete way. The relationship between order quantity and supply leadtime could be specified using any formulation, rather than some restrictive assumptions such as a fixed daily production capacity. This gives TTi the flexibility to define and evaluate its requirement on supplier capacity in various ways.

3.2.4 Performance measures

Three performance measures are defined in this study with respect to the scorecard provided by the SCOR model. These measures represent the performance attributes in term of responsiveness, reliability and cost.

The first performance measure is order fulfillment cycle time, representing a supply chain's responsiveness. For each individual order in this study, the cycle time is calculated as when TTi sent out a PO for final product to the moment when TTi received the corresponding products.

The second performance measure is on time delivery rate representing a supply chain's reliability. It is defined as the percentage of orders that were fulfilled on time, i.e. products delivered within the predefined target cycle time.

The third measure is the average raw material inventory level, an indicator to supply chain cost. It could be calculated by the following formula:

$$\frac{\sum_{t=0}^{T} Inv(t)}{T}, \quad t = 0, 1, 2, ..., T$$

, where Inv(t) is the inventory level at day t, T is the number of days for the time horizon.

3.3 Data Collection and Numerical Results

In general, for an supply chain transformation project, it is indispensable to have a good understanding of customer demands, as-is supply chain operations, and as-is performance. In this case, we've collected a variety of data, including:

- Customer demand history
- Demand fulfillment process
- Time and cost required for each process
- Production policy used at each ODM
- Order-to-delivery lead time of 1 tier suppliers

Figure 5 shows the trend of customer demand for one product. We can easily see that the customer demand fluctuate very much, which represents a big challenge to TTi's supply chain. Note that the real value is disguised due to confidentiality but the demand fluctuation tendency remains as the same.

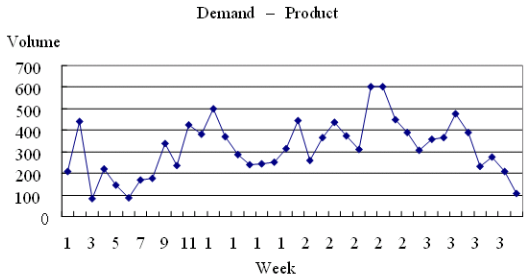

Figure 5: History of customer demand for one product

Considering the high variability of customer demands, the simulation horizon was set as 5 years to cover supply chain dynamics. The warm-up period was set as 300 days, i.e. the simulation data was not taken into consideration until the simulation clock passed 300 days. Warm-up period was used here in order to purge the simulation results and mitigate the impact of initial simulation environment setting on results.

We have conducted a what-if analysis using the simulation model with different parameter setting. Due to space limitation, only the result of one product type is shown and analyzed in the following.

Figure 6 shows that the relationship between the order fulfillment cycle time and base stock level. As the base stock level increases, the order fulfillment cycle time decreases considerably. The figure clearly shows that the introduction of buffer stock for raw materials at ODMs has a considerable impact on the reduction of the cycle time. In this case, TTi would be much more responsive to customer demands.

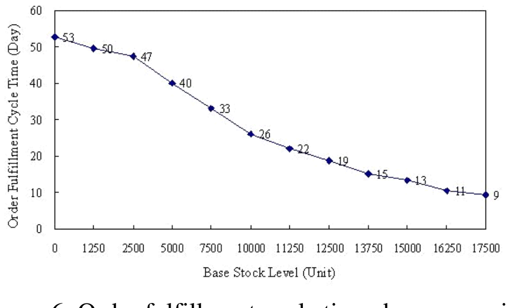

Figure 6: Order fulfillment cycle time decreases with higher base stock level

As the base stock level increases, TTi would benefit from the improvement of its rapid reaction to customer demands. However, there is no free meal in the world. Figure 7 shows that the average raw material stock level gets higher as the base stock level increases. This meant the inventory holding cost increases also. It is absolutely not wise to set a too high base stock level. As the figure shows, with a lower base stock level, the average raw material stock level does not change much since the raw material supply lag much behind customer demands. With a higher base stock level, the stock level increases rapidly because of excessive raw materials supplied. Based on a what-if analysis using simulation, we've obtained the curve shown in Figure 7, where a sensitive area is identified with a base stock level from 12500 to 15000. Provided such a curve, the management team is able to determine the most appropriate parameter setting for inventory control at ODMs.

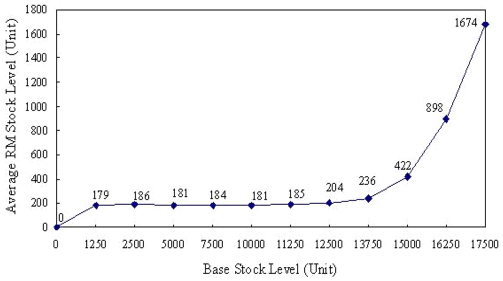

Figure 7: Relationship between base stock level and average RM stock level

Figure 8 shows the relationship between base stock level and on-time delivery rate. Based on our study, the on time delivery rate is very sensitive to the target cycle time. In this experiment, a unique target cycle time is set. While in practice, different order-to-delivery lead time is committed to different customers and for different products. More sensitivity analysis could be conducted to produce more insights for the management team when managing inventory.

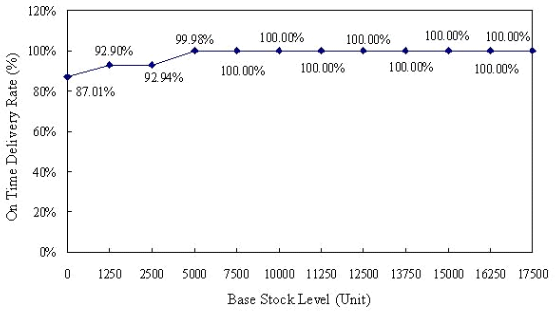

Figure 8: Relationship between Base Stock Level and On Time Delivery Rate

3.4 Implication

From the analysis above, it clearly demonstrated the influences and correlation of introducing raw material buffers at ODMs. With the increase of raw material base stock level, the order fulfillment cycle time will decrease considerably. On the other hand, it may also bring some negative impact to a firm if the base stock is kept at a wrong level, i.e., when the average raw material stock level increases, it will bring additional costs related to inventory holding, management cost, etc.

Thus, keeping the right level of raw material inventory is critical to the firm and overall division profitability. This analysis provides an insightful view to another layer when TTi management team designs its buffer stock strategy at ODMs. Given a different desired service level, this model enables TTi management to reuse the proposed model with corresponding parameter setting and evaluate different operational policies. Certain tradeoff between increased service level and additional costs could be reached based on the quantitative analysis.

4 CONCLUSIONS

For a successful supply chain transformation, it's critical to understand clients' business strength, setup an appropriate goal, use the right model, and conduct the necessary analysis. Simulation is a technique which could help generate insights about transformation, evaluate the to-be scenario in a comprehensive context. Our study demonstrated that the methods and models developed by experts from operations research/management science may be of great help for supply chain transformation and have a lot to play in industry.

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